Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

GEOTHERMAL EXPLORATION AND DEVELOPMENT ACTIVITIES IN GREECE DURING 1995-1999

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Key Words: geothermal exploration, geothermal uses, country update, Greece.

ABSTRACT

The paper reviews the research and development activities in geothermal energy in Greece during the period 1995-1999. Information is also provided on the current status of geothermal direct heat uses. Greece has a great geothermal potential. This potential has been confirmed and verified by the discovery and exploration of new geothermal fields during the past five years (1995-1999). During this period the geothermal research and applications were mainly related to low enthalpy fields. The areas of research include Northern Greece (Thrace, Macedonia), NW Greece (Epirus), Chios and Lesvos islands (Aegean Sea). In Thrace, near the village Aristino, a new geothermal field was discovered, the temperature of which approaches 92ºC. At the area of Sappes (Thrace), some very promising fields were identified through a series of exploration and production wells. Very interesting fields were also discovered in Central Macedonia (Sani and Neo Ryssio district). In NW Greece (Sykies, near Arta, Epirus) the exploration wells brought to light another geothermal field whose temperature is 48ºC. Finally, in Chios Island the recently discovered geothermal field gave temperatures up to 90ºC. Many interesting applications and developments have taken place in Greece during the last five years, such as some additional geothermal heated greenhouses, subsurface soil heating for early asparagus cultivation, production of spirulina using geothermal energy, heating a hotel in the neighborhood of Nea Apollonia hot springs (Macedonia) and a spa complex in Thrace and applications that use heat pumps near Athens and in Rhodes Island. The geothermal power plant in Milos Island has remained shut down since 1989.

1. INTRODUCTION

As is already known (Fytikas 1988; Fytikas et al, 1995 and 1999; Chiotis et al, 1990) there are two high enthalpy geothermal fields in Greece, namely Milos and Nisyros, where seven deep wells identified temperatures of 320ºC and 350ºC respectively. In addition, low enthalpy (T<100ºC) geothermal fields abound in Greece, mainly in the east and north parts of the country, as well as in many Aegean islands. Present data yield a low enthalpy potential exceeding 400 MWt proven and 800 MWt probable. In 1995 geothermal applications were limited to spas and greenhouses.

Greece is rich in geothermal waters, since the greatest part of the country is situated on a geodynamically very active area. During the 1995-1999 period the geothermal potential of Greece, which had already been characterized as significant, has markedly expanded through the continuation of research and productive activities. The bulk of exploration activities were carried out by the Institute of Geological and Mineral Exploration (IGME). A map with the geothermal localities in Greece is shown in Figure 1.

The low enthalpy geothermal research has proceeded at a relative high rate. A significant amount of data and information has been gathered, revealing new geothermal fields (mainly low enthalpy fields, most of which are located in Northern Greece), or expanding the areas of known fields. Even in Western Greece, which is the least favorable territory in terms of geothermics, and particularly in the areas of Antirrio and Sykies, promising data have been acquired.

Geothermal anomalies have been accidentally found in many other areas, mainly Tertiary–Quartenary basins, while a study of existing irrigation wells has triggered the systematic research for new low enthalpy fields. Some of these exploration wells are already in use, while others will be utilized in the future.

In some areas of already known geothermal interest a number of complementary wells were also drilled in order to better determine the field boundaries and the characteristics of the geothermal fluids. Furthermore, in some cases (e.g. in Sidiro-kastro and Therma-Nigrita) the temperatures that had been measured turned out to be higher than the ones already known.

The high enthalpy geothermal applications in the islands of Milos and Nisyros have unfortunately exhibited no progress, mainly because of the negative attitude of the inhabitants to geothermal exploitation. They believe that such exploitation would unfavorably affect the fragile ecological balance. For this reason no further research in the high-enthalpy fields of these islands was carried out.

In summary, the geothermal map of Greece has been enriched considerably during the past five years. On the other hand, the low enthalpy geothermal applications remain relatively few, and are mainly restricted to the agricultural sector. New applications involve underground heating of about 12 ha of asparagus cultivation, spirulina aquaculture, heating of a spa complex, as well as use of heat pumps. Finally, a considerable number of new projects related to the aforementioned applications are about to commence.

2. GEOTHERMAL EXPLORATION

The geothermal exploration in Greece during the past five years is summarized in Table A. A brief description of the most interesting new findings follows.

2.1. Strymon Basin

The Strymon Basin in eastern Macedonia contains several geothermal fields and is one of the largest geothermal regions in Greece, with almost half the geothermal utilization in the country. During the period 1995-1999 the geothermal field of Agistro was explored and delimited, the boundaries of the known geothermal fields of Therma-Nigrita and Sidirokastro were investigated resulting in new data, and exploration took place at the area of Achinos-Ivira which shows geothermal interest.

Remarkable geothermal reservoirs were identified with temperatures in the range 40-75ºC, while additional boreholes drilled by IGME yield over 220 kg/s water. In addition, production tests took place in order to identify the hydraulic parameters of the reservoirs, and studies were carried out regarding corrosion and scaling problems. The result of the new exploration data was the stimulation of the interest for investment and further development.

Agistro: Geologically the area is located at the edge of the line of thrust of the Servomacedonian massive over the Rodopian one. The geothermal reservoir is located at the fractured basement of the metamorphosed rocks of the Rodopian massive, which is covered by a weakly permeable cap which hardly prevents the heat diffusion and the mixing with shallow groundwater. IGME constructed 6 wells (5 exploratory and one productive) reaching depths of 100-300 m, where temperatures of 40-47^{o}C were recorded. During the pumping tests at the productive well the hydraulic parameters were measured, while the exploitable flow rate was of the order of 30 kg/s. Geothermal waters belong to the group of carbonate-calcium-sodium type with a TDS of 0.26 g/L. No corrosion or scaling problems were encountered. The geothermal field extends to an area of 3-4 km^2.

Sidirokastro: During 1995-99 additional exploration was carried out towards north of the existing geothermal field and yielded positive results. The geothermal reservoir is located at the top of the metamorphic basement (marble). Two boreholes were opened, one exploratory, 300 m deep, and one productive, 150 m deep. A geothermal reservoir was located at a depth of 150 m, where temperatures up to 75ºC were identified, higher that the already identified ones. Pumping tests yielded 22 kg/s flow rate. The geothermal water belongs to the group of carbonate-sodium-calcium type with TDS just over 1 g/L. The known extent of the geothermal field was increased to about 14 km^2.

Therma-Nigrita: In the past five years additional exploration in the field of Therma-Nigrita resulted in the increase of the area of the field by at least 3 km^2, since exploration is still under way. The maximum temperature recorded was 64ºC. IGME drilled 7 production wells at depths 80-370 m, yielding over 170 kg/s, 125 of which correspond to self-flowing wells. Moreover, 2 private users opened 2 wells at 100 m and 300 m depth yielding more than 30 kg/s. The temperature of the produced water varies between 40ºC and 64ºC. Geothermal fluids are CO_2-rich and belong to the group of acid carbonate-sodium-magnesium type with a TDS of 1.5-2.5 g/L. The geothermal reservoir is located at a basal conglomerate.

Achinos – Ivira: This is a new area explored in common by IGME and the Aristotle University of Thessaloniki during 1995-99. The exploration yielded an area of 25 km^2 with geothermal interest, with measured temperatures in existing irrigation wells reaching 35ºC at 300 m. Further drilling exploration is under planning in order to estimate the geothermal parameters of the area.

2.2. Rest of Macedonia

Regarding the following geothermal fields, the first three had been already identified by 1994, while the others were discovered during the last five years.

Eratino: Two new production wells, each 670 m deep, were drilled yielding about 100 kg/s artesian flow of 75ºC water. The water originates from the Miocene sediments and the identified permeable horizons at a depth of 550-650 m.

Nymfopetra: A new production well at 120 m was drilled yielding 42ºC water utilized for heating an asparagus cultivation.

Nea Apollonia: Two new production wells 30 m each were drilled by the Aristotle University of Thessaloniki which produce over 100 kg/s water of 56ºC temperature. This water is transported 300 m away to a completed, but not in operation, spa complex for balneological and heating purposes.

Neo Ryssio: The field is located near the Thessaloniki airport area. One 600 m deep exploratory well was drilled, which revealed an interesting geothermal gradient within the Quartenary-Miocene sediments. Important reservoirs are expected inside the middle Miocene sediments at a depth of about 800 m depth with a temperature of 60ºC.

Sani-Afytos: Three exploratory wells were drilled down to 600 m identifying 40ºC of bicarbonate fluid with artesian flow.

Irinoupoli: Two exploratory wells identified a 27ºC fluid of high salinity at 400 m.

Nissi: Two exploratory wells identified 35ºC of low salinity fluid and high productivity at 500-580 m.

Limnochori: Within the basin, two exploratory wells yield over 30 kg/s water of 38ºC from the top of the metamorphic basement, at 200 m depth.

Florina: Wells drilled for irrigation accidentally identified an area of geothermal interest near the city, along an important fault system. Two 350 m deep production wells yield 110 kg/s of 27ºC water. In this area the geothermal water is CO_2 rich.

2.3. Thrace

In Thrace geothermal research improved our knowledge of known geothermal localities (first four of the following fields), while two new geothermal fields were also identified

Aristino-Aetochori: Exploration carried out enlarged known extent and increased known temperature to 92ºC. A new well yields over 60 kg/s flow rate from 300 m.
Neo Erasmio: Three production wells were drilled yielding 60ºC of artesian water. The flow rate of one of them alone is 60 kg/s.

Traianoupolis: Two production boreholes were opened within the area of the springs, yielding about 30 kg/s of 52°C water of water, which is used for the heating system of a community spa complex (Angelidis, 1999).

Porto Lagos: Two new production wells were drilled at 450 m yielding 38ºC extended the known geothermal field of Nea Kessani towards South-East. This water could be utilized for anti-frost protection of the artificial ponds where fish are grown.

Sappes: A new geothermal field (25 km^2) was discovered by drilling 4 exploration and 3 production wells. A very important reservoir located mainly at the Tertiary volcanics interbedded in the sediments provide artesian flow of fresh water at ~40ºC.

South Komotini: A sparse matrix of five exploratory wells indicated a new geothermal area of 30 km^2 with 40ºC temperatures, confirming the geothermal interest of the region.

2.4. Aegean Islands

Chios Island: The area of Nenita on the island has been explored, where a geothermal field was identified. Its reservoir is located within the mesozoic limestones which are covered by impermeable sedimentary formations. Five exploration boreholes were opened, which located the geothermal reservoir at 300-400 m depth with water temperature up to 90ºC. The geothermal field area identified is over 5 km^2. At present, a production well is under construction aiming at evaluating the reservoir hydraulic parameters, flow rate and chemistry of the geothermal fluids, which appear to belong to the group of sodium-chloride type with TDS>>4 g/L.

Lesvos Island: The Public Power Corporation (PPC) has financed a program of exploration work including drilling (Koutroupis, 1999). At a first step 9 shallow wells were opened in the area (6 in Stipsi and 3 in Argennos). Temperatures measured were 92ºC and 86ºC, respectively, at a depth of 200 m. In a second step, 3 deeper wells (up to 600 m) were added at these areas confirming the anticipated results. PPC plans to start a deep drilling program of 3 wells around 2 km deep by the beginning of 2000.

Therma, Samothraki: Three wells were drilled within the thermal area near existing spas, reaching a depth up to 120 m and yielding a high flow rate of fluid of high salinity and up to 100ºC temperature (Angelidis, 1999). Further development plans include construction of a modern spa center, heated by geothermal energy.

Kimolos: In the frame of a project for desalination in Kimolos Island, two wells were drilled in 200 m depth and an aquifer was found with waters reaching 60°C in large quantities.

2.5. Epirus – North-West Greece

Sykies Artas: Two exploration and one production well at 300 m depth were opened, identifying a geothermal reservoir within the limestones at temperatures 40-45ºC, covering an area >1 km^2. Exploration continues. Geothermal waters belong to the group of Na^+, Ca^{++}, Mg^{++}, HCO_3^-, Cl^- with TDS~4 g/L containing CH_4 and H_2S gases.

Konitsa: Exploration is underway. The first well reaching a depth of 300 m, located a temperature of 38ºC within the limestones. Water chemistry probably belongs to the group of magnesium sulphate with a TDS of 1.3 g/L.

Antirrio: Exploration is underway, where the first well encountered temperatures of 38ºC at 150 m.

2.6. Rest of Greece

Paschalitsa, Sofades, Thessaly: Exploration is underway. The first well has reached a depth of 430 m. Expected temperatures are of the order of 65°C at 700 m.

Kavouri, Athens: Two wells of 120 m depth each were drilled for production/reinjection purposes by a private user. Each one yields over 4 kg/s water of high salinity and 36ºC temperature with a submersible pump. Water level is at about 5 m. Both wells are located 500 m from the sea at sea level.

3. DEVELOPMENTS IN ELECTRIC USES

Table 1 gives the present and the planned production of electricity in Greece. Regarding geothermal energy, no electricity was produced from the only geothermal plant in Greece (2 MWe), on Milos Island (Table 2). In the past year the Public Power Corporation has started work towards the installation of an Organic Rankine Cycle plant on the island of Lesvos. The progress in its exploration program has been reviewed earlier.

4. DEVELOPMENTS IN DIRECT USES

Direct heat uses in operation during the winter 1998-1999 are listed in Table 3. Most applications refer to greenhouse and soil heating. During the period 1995-1999 the thermal capacity of direct heat projects in operation (excluding spas) increased by about 6 MWt to reach 22 MWt, representing an annual energy utilization of 221 TJ/yr (Table 5).

A negative development in the direct uses in Greece is that the infrastructure in the field of Nea Kessani, Thrace, which was completed in 1994, remains unexploited due to managerial problems. Also in Soussaki, near Athens, preparations and plans for installing a desalination unit and other geothermal applications have been abandoned.

4.1. Space heating

The only noteworthy new space heating project in operation refers to a spa complex in Traianoupoli, Thrace. A titanium plate heat exchanger is employed to isolate the relatively high salinity geothermal fluid from the heating loop. A second project for heating a new spa complex in Nea Apollonia has been completed, but it has not been put in operation. Two house-office buildings, one in Neo Erasmio and the second in Nea Apollonia, are also heated by geothermal energy using floor radiant panels. In Milos, a house is heated by radiators with a downhole heat exchanger in a shallow well (30 m, 90ºC).

4.2 Greenhouse and soil heating

The most significant development in this sector was the establishment during the last three years of about 12 ha of soil

heating for asparagus cultivation in Macedonia and Thrace. The soil heating is accomplished by the direct flow of the geothermal water through corrugated polypropylene (PP) pipes with an inside diameter of 28 mm, placed underground.

In the period 1995-1999 the geothermal greenhouses were expanded by 5 ha, although about 3 ha of mostly community-owned greenhouses were out of operation either temporarily or permanently. Thus, the net increase in the greenhouse area was only 2 ha during the five-year period. Only 10% of the geothermal water used in this sector pass through plate heat exchangers, while the remaining 90% passes directly through plastic or metallic pipes (Andritsos et al, 1999). The corrugated PP pipes are employed in the 70% of the greenhouse area. Other pipes used include soft polyethylene (PE) ducts (~0.2 m in diameter), polyvinyl chloride (PVC), and metallic pipes. Despite the abundance of geothermal waters in Greece reaching up to 100ºC, the vast majority (~75%) of the geothermal waters used in greenhouse and soil heating have temperatures less than 50ºC.

4.2. Bathing, Spas

At present, thermal spas and bathing centers operate at 56 locations in Greece. During the last few years several bathing complexes were expanded or renovated (Nea Apollonia, Sidirokastro, Smokovo, Langadas and Tryfos). New spas have been constructed in Kyllini, Edipsos, Pikrolimni, Amarantos, Ammoudara Kastorias, Spercheiada, Nigrita, Polychnitos (Lesvos Island) and Kythnos Island. Despite the construction of new units, the demand for spas has remained stagnant during the traditional balneological period (June-October). On the other hand, an interest is seen for bathing all year long and several spa resorts remain open all year. No systematic work has been carried out in Greece to estimate the heat use in the spa section. The total water flow from the Greek spas exceeds 1000 kg/s, with water temperatures in the range 18-90ºC. A conservative estimate (assuming the water leaving the bathing centers has a temperature of 30ºC) of the total thermal capacity of the Greek spa resorts is 35 MWt, with a load factor of 0.15.

4.3. Other direct uses

A geothermal desalination plant using low enthalpy geothermal water and electric power is under construction in the island of Kimolos. Another application involves the cultivation of spirulina (green-blue algae) in temperature controlled ponds in Therma-Nigrita utilizing both geothermal heat and CO_2. The plant in the past year produced about 2000 kg of dried spiroulina. A project in Milos for desalination utilizing low enthalpy water (90-100^{o}C) from shallow bores (50-100 m) has been approved for financing by European programmes.

4.4. Geothermal Heat Pumps

During the last five years two geothermal heat pumps were installed in Greece used for both heating and cooling (Table 4). The first one was in a private house in Kapandriti near Athens (35 kW rated power) and the second in the Municipal building in Rhodes city (140 kW rated power). Estimated COP is 4 for both pumps.

In addition, a heat pump coupled with ground heat storage uniformly distributed below the buildings basement used for heating and cooling the 6000 m^2 building of THENAMARIS SHIP MANAGEMENT offices was converted to geothermal by utilizing the warm water (36ºC) of a well. The utilization of the geothermal water as a heat source/sink helped overcome problems of extremely low efficiency arising from overheating of the storage media during the summer (>80ºC) and its overcooling during the winter (0ºC). This extremely low efficiency caused inability of the heat pump to provide the desired indoor temperatures, especially late in both seasons and under severe weather conditions the inability of the heat pump to operate at all. The heat pump rating is 220 kW.

Water source geothermal heat pumps are under construction in Nea Apollonia, Langadas and Milos and ground source in Thessaloniki (Pylaia) and Athens.

The geothermal heat pump uses should have a tremendous growth following the trends in other countries. Unfortunately, there is lack of proper information to the public and of operating demonstration projects. Actually, a large demonstration project at the Technical University of Athens remains incomplete.

5. WELLS DRILLED

Eighty seven new wells, of which 46 are production wells, were drilled during 1995 to1999 (Table 6), as compared with the 41 wells drilled during 1990-1994 (Fytikas et al, 1995). The average depth of the exploration wells is 340 m and that of production wells is 270 m. The deepest production well is 670 m.

6. PROFESSIONAL PERSONNEL

The allocation of professional personnel to geothermal activities during the period 1995-1999 is shown in Table 7. There is a noteworthy reduction in the personnel, especially when compared with the personnel in the period 1985-1989, because of the discontinuation of the Milos plant and the reduction of research projects in the geothermal sector from the European Commission.

7. INVESTMENT IN GEOTHERMAL

Unfortunately, an exact estimate for total investment to geothermal activities prior to 1995 is difficult to make. A gross estimate is 50 million US$, almost 100% funded by public funds, a significant part of which dealt with the research and development of the high-enthalpy fields of Milos and Nisyros Islands.

During the last five years the investment in research and field development is estimated to 2.5 million (in 1999) US$, of which more than 90% is funded by public funds. In the same period investment in direct uses went to asparagus cultivation (~12 ha), greenhouse expansion, a spa complex heating and a desalination plant in Kimolos Island, which is close to completion. The investment in these direct uses (excluding cost for drilling and surface development) is estimated to 1.7 million (in 1999) US$, with the private sector funding standing to about 40%.

8. CONCLUSIONS

During the last five years drilling of irrigation wells, as well as intensive exploration activities focused in low enthalpy fields, confirmed the rich geothermal potential of Greece and identified new areas of geothermal interest. Measured low enthalpy geothermal potential exceeds 400 MWt. Despite the abundance of up to 100ºC fluids, the majority of geothermal direct applications use fluids with temperatures below 50ºC. This is due to the mild climate conditions prevailing in the country, coupled by the practical absence of technical problems when dealing with low temperature geothermal fluids. High enthalpy exploration and development remained stagnant.

During the period 1995-99 geothermal capacity of direct heat projects in operation (excluding spas) increased by 40%, representing an annual total energy utilization of 221 TJ. New geothermal development include mainly balneological and agricultural uses, such as heating of spa resorts and greenhouses, subsurface soil heating of asparagus cultivation and supply of both heat and CO_2 to blue-green algae growth media. Other new uses include geothermal heat pumps and space heating at small scale. New projects are under construction or planned, such as water desalination, air conditioning via geothermal heat pumps, as wells as new greenhouses.

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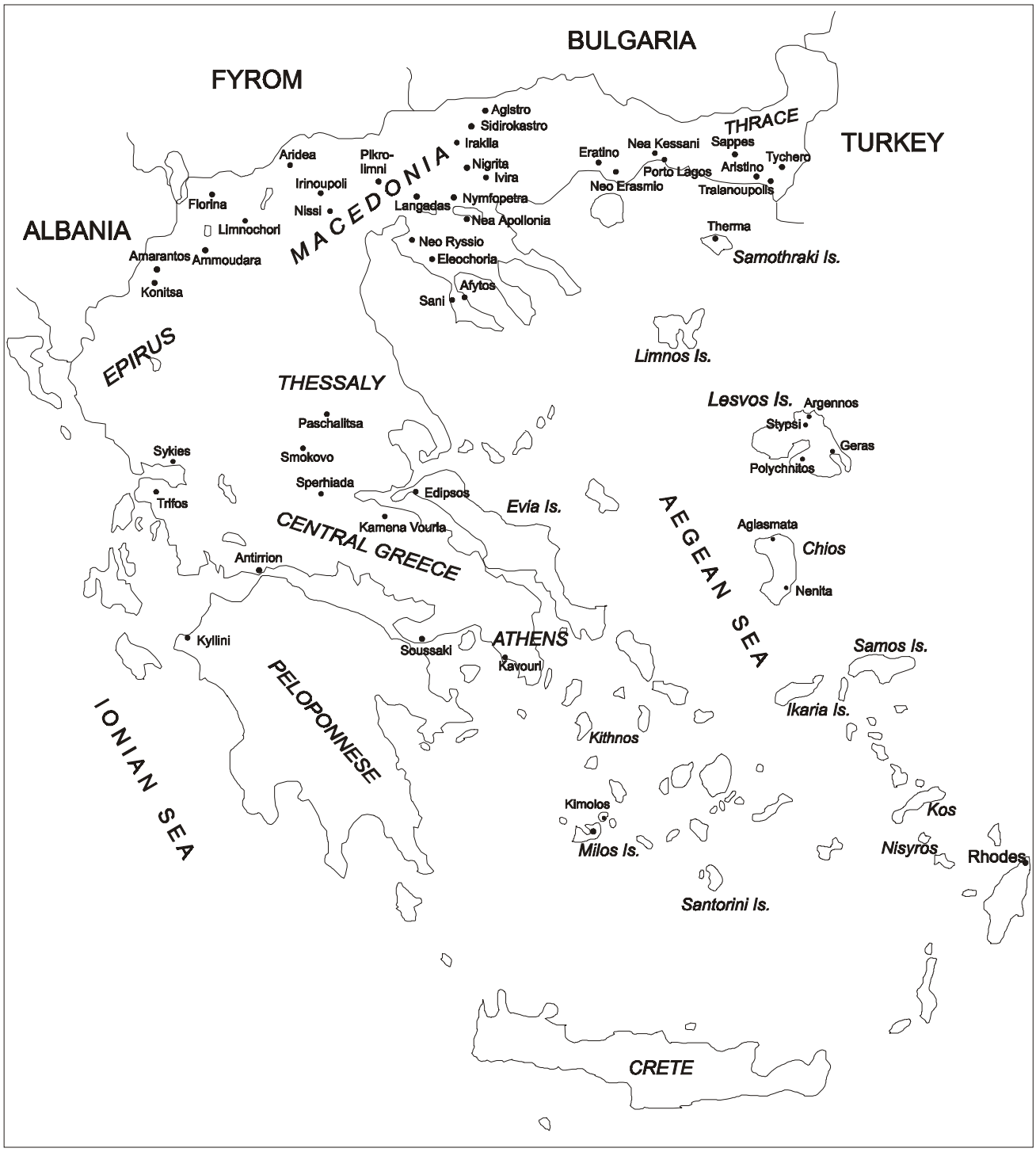


Figure 1. Geothermal localities in Greece.

TABLE A: MAIN CHARACTERISTICS OF RECENTLY EXPLORED GEOTHERMAL FIELDS IN GREECE

Geothermal Field	Surface area (km^2)	Reservoir depth (m)	Total flow rate (m^3/h)	T_{max} (°C)	T.D.S. (g/L)	Type of water	Wells expl./prod. (<1994)	Wells expl./prod. (1995-1999)
THRACE								
Aristino-Aetochori	30	350-450	400	92	12	Cl-Na	6/0	3/2
Traianoupoli		50-150	100+	52	8	Cl-Na	0/1	0/2
Sappes	25+	400	500	40	1-2	HCO_3-Ca	0/0	4/3
Tychero		400	500	38	1.5	Cl-Na-HCO_3	0/0	0/2
Neo Erasmio	10	200	400	60	1	Cl-Na-HCO_3	11/3	0/3
Porto Lagos		450	20	38	5	Cl-Na	0/0	0/2
South Komotini	30	450		40			0/0	5/0
MACEDONIA								
Agistro	3-4	100-300	100	47	< 0.3	Ca-Na-HCO_3	0/0	5/1
Sidirokastro	14	20-400	250	75	1,5	Cl-Na-HCO_3	16/5	0/3
Nigrita	20	370	1000	64	2.5	Na-Ca-Mg-HCO_3	9/6	0/9
Iraklia	25	200-400	200	62	1-2	HCO_3	8/0	1/0
Achinos - Ivira	25	300		35				
Eratino		500-650	300	75			0/0	0/2
Nea Apollonia	4+	30-110	600	56	1+	SO_4-HCO_3-Na	3/2	0/2
Nympfopetra	2	60-110	300	45	1+	SO_4-HCO_3-Na	5/1	0/1
Neo Ryssio		500+		40+	2	HCO_3	8/0	1/0
Sani - Afytos	6	500-600		38	1-2		0/0	3/0
Irinoupoli		400		27	15	Cl-Na	0/0	2/0
Nissi		500-580		35	1		0/0	2/0
Limnochori		200	>100	38	1		0/0	0/2
Florina		350	400	27			0/0	0/2
AEGEAN ISLANDS								
Argennos (Lesvos)	4	10-300	800	86	12	Cl-Na	0/3	3/1
Stipsi (Lesvos)	10	50-200	200+	95	1-5	Cl-Na	0/3	6/2
Nenita (Chios)	5+	300-400	100	90	4+	Cl-Na	3/0	5/1
Therma, Samothraki		40-120	100	100	40	Cl-Na	0/0	0/3
Milos	50	10-100	200	90	5-30	Cl-Na	25/0	0/1
Kimolos		170-200	200	60	40	Cl-Na	0/0	1/2

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICTY

(approximately)	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specifiy)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in January 2000	(2)	-	8000	38000	3000	4000	-	-	wind 26	wind 43	11000	42000
Under construction in January 2000	-		800		200		-				1000	
Funds committed, but not yet under construction in January 2000											~ 1 billion Euro	
Total projected use by 2005	2 - 3	0 - 2	9000	43000	3500	4500	-	-	30	50	12500	47500

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 1999

[1] N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

[2] 1F = Single Flash; 2F = Double Flash; 3F = Triple Flash; D = Dry Steam; B = Binary (Rankine Cycle); H = Hybrid; O = Other (please specify)

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1]	Type of Unit[2]	Unit Rating MWe	Total Installed Capacity MWe	Annual Energy Produced 1999 GWh/yr	Total under Constr. or Planned MWe
Milos	Milos Pilot Plant	1987	1	R	1F	2	2	10 (1988)	-
Lesvos									1
Total			1			2	2	-	1

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 1999

[1] I = Industrial process heat; C = Air conditioning (cooling); A = Agricultural drying (grain, fruit, vegetables); F = Fish and animal farming; S = Snow melting; H = Space heating & district heating (other than heat pumps); B = Bathing and swimming (including balneology); G = Greenhouse and soil heating; O = Other (please specify by footnote)

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
Nigrita 1	G	20.0	58	38			1.67	6.67	17.6	0.33
Nigrita 2	G	13.9	41	28			0.76	5.00	8.57	0.36
Nigrita 3	G	7.0	37	25			0.35	2.90	4.59	0.41
Nigrita 4	G, O*	20.0	45	30			1.26	7.00	13.9	0.35
Nigrita 5	G	16.7	37	20			1.19	4.20	9.42	0.25
Sidirokastro 1a	G	10.0	48	34			0.59	3.50	6.46	0.35
Sidirokastro 1b	G	7.8	63	35			0.91	2.80	10.3	0.36
Sidirokastro 1c	G	8.3	43	32			0.38	3.00	4.35	0.36
Sidirokastro 2	G	14.0	37	25			0.70	5.80	9.18	0.41
Langadas 1	G	6.0	36	15			0.53	2.00	5.54	0.33
Langadas 2	G	8.4	37	23			0.49	2.80	5.17	0.33
Langadas 3	G	6.0	35	22			0.33	2.00	3.43	0.33
Nymfopetra	G	14.0	45	20			1.46	3.00	9.89	0.21
Nea Apollonia 1	G	7.0	46	32			0.41	2.50	4.62	0.36
Nea Apollonia 2	G	14.0	42	27			0.88	4.80	9.50	0.34
Nea Apollonia 3	G	11.1	45	30			0.70	3.70	7.32	0.33
Nea Apollonia 4a	G	10.0	46	28			0.75	3.50	8.31	0.35
Nea Apollonia 4b	G	7.0	32	22			0.29	2.60	3.43	0.37
Nea Apollonia 5	G	10.0	45	27			0.75	2.40	7.67	0.34
Eleochoria	G	5.6	30	20			0.23	1.80	2.37	0.32
Neo Erasmio	G	16.7	60	30			2.10	3.50	13.9	0.21
Polychnitos	G	16.7	80	35			3.14	5.60	33.2	0.34
Geras, Lesvos	G	5.6	38	25			0.30	1.90	3.26	0.34
Milos	G	4.2	46	24			0.39	1.00	2.90	0.24
Traianoupolis	H	16.7	52	37			1.05	6.30	12.5	0.38
Neo Erasmio	H	1.0	60	40			0.08	0.33	0.87	0.33
TOTAL		258					21.7	90.6	218	0.32

* Spiroulina cultivation

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF DECEMBER 1999

[2] V = vertical ground coupled, H = horizontal ground coupled
W = water source (well or lake water), O = others (please describe)

Locality	Ground or water temp. (°C)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP	Equivalent Full Load Hr/Year	Thermal Energy Used (TJ/yr = 10^{12}J/yr)
Kavouri, Arthens	36	220	1	W	4	3600	2.1
Kapandriti, Athens	17	35	1	W	4	1200	0.1
Rhodes	17	140	4	W	4	2400	0.9
TOTAL							3.1

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 1999

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr = 10^{12} J/yr)	Capacity Factor
Space Heating	1.13	13.3	0.37
Air Conditioning (Cooling)			
Greenhouse Heating	20.6	205	0.32
Fish and Animal Farming			
Agricultural Drying	-		
Industrial Process Heat	-		
Snow Melting	-		
Bathing and Swimming	(35)*	(164)*	(0.15)*
Other Uses (specify)			
Subtotal	21.7	218	0.32
Geothermal Heat Pumps	0.40	3.1	0.25
TOTAL	22.1	221	0.32

* conservative estimate, not included in the total

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1995 TO DECEMBER 31, 1999

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration	(all)	9	32			14.0
Production	>150° C					
	150-100° C					
	<100° C	3	43			12.5
Injection	(all)					
Total		12	75			26.5

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	2	26	6	-	8	3
1996	-	25	6	-	6	3
1997	-	25	4	-	5	3
1998	-	25	4	2	6	3
1999	-	23	4	2	6	3
Total	2	124	24	4	31	15